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Bulletin No. 12. S. 14.

U. S. DEPARTMENT OF AGRICULTURE.

DIVISION OF SOILS.

THE ELECTRICAL METHOD

OF

MOISTURE DETERMINATION IN SOILS:

RESULTS AND MODIFICATIONS IN 1897.

BY

FRANK D. GARDNER,
Assistant, Division of Soils.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
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LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
DIVISION OF SOILS,
Washington, November 24, 1897.

SIR: I have the honor to transmit herewith some results of the electrical method of moisture determination in soils from the experience of the present season. Mr. F. D. Gardner was assigned to the immediate supervision of this field work early in the year. He organized a small but efficient corps of observers among the farmers of the several localities which it was desired to study. These observers have intelligently and faithfully carried out their instructions and have amassed a quantity of valuable data concerning the water content of their several soils. Widely different sections of the country and different types of soil were purposely selected to give the method a thorough practical test. The results have been very satisfactory.

Certain changes have been suggested from the experience of this season which will simplify the construction of the apparatus and cheapen the cost of the instruments, at the same time simplifying the final calculation of the results. It is desirable to give these suggestions wide and immediate publicity for the benefit of those who are planning to take up this line of soil investigation.

I recommend that this be published as Bulletin No. 12 of this Division.

Respectfully,

MILTON WHITNEY,
Chief of Division.

Hon. JAMES WILSON,
Secretary of Agriculture.

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ELECTRICAL METHOD OF MOISTURE DETERMINATION IN SOILS: RESULTS AND MODIFICATIONS IN 1897.

The electrical method of determining the moisture content of arable soils, described in Bulletin No. 6 of this Division, has been thoroughly tested during the present season, and has given very great satisfaction. Fourteen sets of the instruments were placed in the hands of farmers located in widely different sections of the country, and on markedly different types of soil. Observations were made daily of the electrical resistance of the soil at the depths of 1 to 3, 3 to 6, 9 to 12, and 21 to 24 inches, except in a few instances where the 1 to 3 inch depth was omitted on account of the very loose and dry condition of the surface soil. The observations were taken during the crop season of the particular locality and extended over periods of from three to four and a half months, the average time being approximately four months for each observer. There were fifty-six electrodes in constant use.

The experience gained by the practical use of the method in the field makes it appear desirable to describe some slight modifications in the apparatus and in the method of its operation, which will greatly facilitate the taking of the observations and the calculations of the results.

MODIFICATION OF THE ELECTRODES.

The electrodes, as previously described, consist of two thin strips of carbon cemented onto a block of wood with marine glue, with a compensating temperature cell mounted between them. The compensating cell consists of a glass tube with platinum electrodes fused into either end, the tube being nearly filled with a salt solution. The wooden block is in two parts, fitted together with a tongue and groove in such a way that the parts will slide over each other with a wedging motion. One of the wires of the compensating cell is soldered to one of the carbon plates which has previously been copperplated. Insulated wires are soldered to each of the electrodes and to the free end of the temperature cell and are carried to the measuring instrument. In placing the electrodes, an inch and a half auger hole is bored into the soil, a suitable stick is screwed onto the top end of the block, and it is lowered into the hole to the proper depth. Then, the wires being held in one hand, the wedge is tightened up by sharp blows on the top of the stick until the electrodes are firmly bedded into the soil at the side of the hole. A number of electrodes can be put into the same hole if put at sufficient distance apart so that they will not interfere. Before placing the electrodes it is necessary to see that there are no bubbles in the solution between the platinum electrodes of the temperature cell. If any are found they must be removed by gently jarring the block against one hand or by swinging it up and down suddenly. After placing the electrodes next fill the hole with melted pitch in order to prevent any accumulation of water and to insulate properly the wooden blocks and the wires leading therefrom. Certain modifications and precautions have been found necessary, as mentioned below.

In the preparation of these electrodes special care should be taken to insulate the carbon strips. The wooden blocks are previously boiled in linseed oil or thoroughly covered with several coats of asphalt varnish, which is preferred to the soaking in oil. In order to prevent the wire from breaking off from the temperature cell a small tack is driven into the wood, the wire from the temperature cell is soldered to this, and the main wire leading out to the measuring instrument is soldered also to the tack. Care must be taken not to burn the marine glue, as this reduces it to carbon, which is a good conductor of electricity. From some cause the insulation in some of these electrodes has not been perfect. Water seems to have leaked in, and while there has been no apparent trouble in the resistances of the soil itself, and even where the moisture records are thoroughly satisfactory, the temperature cell in some cases had evidently too low a resistance, owing probably to short-circuiting. It is therefore advisable to take every possible precaution to insure a thorough insulation. Where the compensating cells are to be used to take the temperature of the soil a strip of glass should be mounted on the face of the wooden block to insure more complete insulation of the parts.

In very light, sandy soils, having a low salt content and small water capacity, the resistance of the soil with the ordinary form of electrode with two strips of carbon is sometimes very high, and in dry periods is liable to extend beyond the capacity of the measuring box. In such cases it is well to add several extra carbon plates to the electrode, separating them about a quarter of an inch from the other plates by glass rods. Where the electrode is composed of several plates, the alternate ones are joined together with a short piece of wire soldered to each. This will give several paths for the electric current, and will lower the resistance. If it be found that the electrode thus constructed gives too low a resistance, one of the wires can simply be cut and one or more of the carbon plates cut off. For the surface of very dry, sandy soils electrodes having as many as six or eight carbon strips have been used with great success.

In the case of very loose, sandy soils, or with plowed land of any kind, it is better not to use the wooden block, but to mount the electrodes on a strip of glass. In this case it is well to join the wires to the bottom of the electrodes and use well insulated wires in a lead-covered cable laid under the surface of the ground to insure complete insulation of the wires leading from the electrodes. These electrodes for shallow depths should be buried with the faces of the electrodes pressed firmly against the perpendicular wall of a small excavation made for the purpose, while the loose earth is firmly packed around the sides and back.

Where the connections with the measuring box are by overhead wires, the insulation should be as nearly waterproof as possible, and the wires should be separated and run directly to the underside of the box containing the measuring instrument, which should be kept as dry as possible. Where ordinary gas fixture or office wire is to be used, it should be well protected with pitch applied to a height of several inches above the ground.

Where the electrodes are buried in the auger hole and the hole filled with pitch, it is very essential that the pitch should not be allowed to spread out at the top over an area larger than the auger hole, as it forms a covering over the electrode, which acts as a mulch and retards the escape of moisture from around the electrodes, affecting the results to a marked extent.

UNDERGROUND CABLES FOR CONNECTING ELECTRODES.

Lead-covered wires can be purchased in the market at but a very slight increase in price over the ordinary waterproof insulation. By means of lead-covered three-conductor cables the electrodes may be joined through underground connections with the measuring box and the field or plot left perfectly free for the ordinary operations of the farm. The cable should be securely attached to the bottom of the electrodes in the case of shallow depths, or to the top of the electrodes in the case of more deeply buried connections. As little wire as possible should be exposed outside of the lead covering, and this must be thoroughly insulated after being soldered. The rest of the cable is then buried under the soil in a narrow trench and at such a depth that the ordinary operations of cultivating, hoeing, or plowing, can be carried on without any injury whatever to the electrodes. In the case of shallow electrodes, however, a stake should indicate the position, and care must be taken in working around them, just as in the case of plants. The other end of the lead-covered cable should go up into the box. With proper precautions in insulating at either end there is thus no danger of short-circuiting. The cables may be of any length, and those from a number of fields or plots can be brought together to a single measuring box.

The accompanying figure (fig. 1) shows the measuring box in place with six cables leading up into it and joined to two switch boards.

In case of underground cables which are to be permanently buried and used for a number of years, it is well to put each electrode in a separate hole; then, in case any one of them is rendered useless for any reason, it can be taken up and the cable used for another set of electrodes without disturbing any of the others. Otherwise it may be necessary to abandon the cable for fear of disturbing the other electrodes.

IDENTIFICATION OF THE WIRES AFTER BURYING ELECTRODES.

In using underground cables for connecting the electrodes to the switch board great care should be taken to pick out the ends of the wires at each end of the cable and number or label them, so as to know which one is attached to the compensating cell and which to each of the carbon strips. In case, however, this should not be done, or in case the wires should in any way get mixed up, they can be identified, provided the three wires coming from any one depth are kept together.

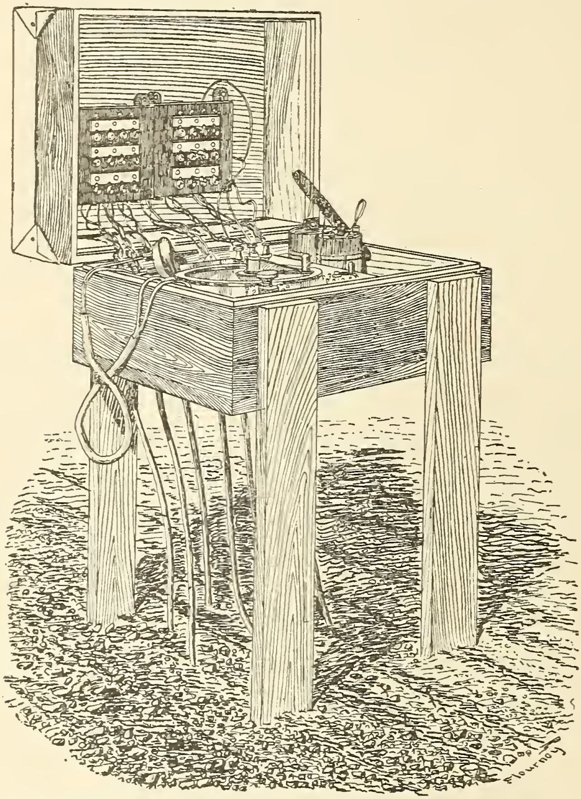


FIG. 1.—Electrical measuring box for soil moisture determinations in position and in field.

Put the lower right-hand switch of the measuring box on the point marked "moisture," then join the three wires to the three binding posts in any order. It is only when the combination wire—that is, the wire attached to the carbon strip to which the temperature cell is also attached—is joined to the middle binding post that a balance can be obtained in the telephone. When this is found, label it; then put the switch on the point marked "plates" and take the resistance. Then take out the wire from the right-hand binding post and put the third wire in its place. Take the resistance of this also. If the approximate resistance of the temperature cell is known and there is much difference in the two resistances which have just been taken, the wire leading from the free end of the temperature cell can probably be picked out without trouble. If, however, the resistances which have thus been taken are nearly the same, it will be necessary to proceed differently. In this case, keep the switch on the point marked "plates," and attach the wire from the free carbon of another set of electrodes to the middle binding post. Then attach in turn each of the two wires which it is desired to identify to the right-hand binding post and take the resistance. The resistance of the wire coming from the temperature cell will be higher than that coming from the carbon, as the current will have to go through the temperature cell and out from the attached carbon and the resistance is thus increased by the resistance of the compensating cell itself. In this way it is easy to identify the three wires coming from any one depth.

As a proof of the correctness of the combination and to test the insulation of the parts, it is well to take the resistance of the plates, of the compensating cell, and of the combination for moisture. The resistance of the plates alone, divided by the resistance of the compensating cell alone, and multiplied by 1,000, should give the resistance of the combination ("moisture") within a few ohms.

CLEANING THE INSTRUMENTS.

The brass switches and contact points of the inside of the measuring box, as well as the brass plugs and holes in the switch board, should be kept clean and bright to insure perfect contact. The finest grade of emery cloth should be used for this purpose, and it is preferable to rub this off to a certain extent before using, so that it shall not scratch, but merely polish the surface. In cleaning the holes in the switchboard a small piece of the emery cloth about one-half inch square is slipped into the slit in one of the split brass plugs; then by inserting the plug and turning it several times in the hole it will insure a perfectly clean and bright surface. The measuring box must be kept perfectly dry and should be cleaned at least once in three or four weeks. The handle should be taken off, the top thrown open, and the contact studs, shoes, and switches well cleaned. Attention should be given to the point of the set-screw and the platinum tip on the tuning fork, as these are liable to become coated with grease, dust, or oxide, and either stop the instrument frequently or give a rasping sound in the telephone. These should be taken out and carefully cleaned with emery cloth, and then very carefully adjusted again. Some of the small irregularities in the results are undoubtedly due to a lack of systematic cleaning of the contacts in the instruments, and an accumulation of grease and dirt on the metal parts in the exposed position, and the rough usage the instruments have been subjected to.

STANDARDIZATION OF THE ELECTRODES.

Electrodes should be allowed to remain at least a week in position in the soil to allow them to settle before being standardized. It is well to have them buried immediately before a rain, to insure a quicker settling of the soil around them. It has been found, as the result of this year's experience, that it is only necessary to standardize the electrodes once or twice during the season. In most cases a single standardization is all that is necessary, as the variation in the resistance, with changing moisture conditions, has a definite and constant value. It is, however, very essential that this standardization should be done as accurately as possible. Owing to the inequalities in the soil and the impossibility of taking samples which will agree closely in their moisture content, it has been found necessary to take at least 16 samples from around each electrode at a sufficient distance so that the electrode shall not be disturbed. These samples may all be put together and a composite sample taken for moisture determination; or, what is better, 4 composite samples should be made, each containing 4 samples. This gives some check upon the accuracy of the result and makes the labor much less than if a separate moisture determination were made in each sample. Great care must be taken to have the samples represent the exact depth at which the electrodes are buried and in taking the samples to prevent any of the surface soil from dropping into the hole and becoming mixed with the sample.

In order to test the method of standardization more thoroughly the plat containing the instruments at Takoma Park, D. C., which had been very thoroughly prepared, was divided into 16 parts, and in each of these 4 samples were taken and mixed for a composite sample. The accompanying diagram (fig. 2) gives the moisture determinations in each of these sixteen composite samples.

(1) 17.0	(5) 22.0	(9) 21.5	(13) 20.0
(2) 17.4	(6) 20.9	(10) 23.5	(14) 22.0
(3) 19.5	(7) 21.8	(11) 24.1	(15) 23.6
(4) 21.5	(8) 24.5	(12) 23.3	(16) 22.5

FIG. 2.—Diagram showing moisture determinations for sixteen composite samples of soil.

The plat was free from vegetation, and had been kept free for some months. The samples were taken at a depth of 0 to 3 inches and were very carefully collected, and the moisture determinations were made in the most careful manner. The average of these 16 composite samples is 21.5 per cent. The difference between the highest and lowest is 7½ per cent. The average of the upper left-hand quarter of 16 samples is 19.2 per cent; of the lower left-hand quarter of 16 samples, 21.8 per cent; the upper right-hand quarter is 21.5 per cent, while the lower right-hand quarter is 23.4 per cent. The difference here between groups of 16 samples amounts to 4.1 per cent. This difference is probably somewhat greater than if the samples had been taken to a greater depth, but it has been the common experience of all our observers that the differences in the moisture content of samples taken anywhere to a depth of 2 feet in apparently very uniform soils, and taken in precisely the same way on the same day, are quite considerable. It is therefore necessary to take a large number of samples in order to reduce the probable error to a small value.

Objection has been made to this electrical method of moisture determination on account of the single position represented by the electrode. The electrode might happen to have been put into a place having a large moisture content or a small moisture content, either more or less than the average of the field. This may be corrected, possibly, by a modified form of electrode, which is being worked on, in which eight or ten points can be joined together. Still, as the absolute moisture content is not so important as the relative moisture content from time to time, the variation at the single spot at which the electrode is buried is undoubtedly much more accurate and better suited to practical purposes than samples taken from different places, in view of the great variation which is found in samples taken on the same day. The electrodes show the variation at that point, and whether this is higher or lower than the average of the field, the variation at that point is probably proportional to the variation in the whole field.

It follows from what has been said that it is somewhat difficult and unsatisfactory to compare the electrical method with the actual moisture determination of samples taken daily, on account of the variation in the moisture content of the soil. It will be shown, however, that such comparisons have been made, and that the two methods agree within the limit of error of the ordinary moisture determination.

RESISTANCE BETWEEN SOIL ELECTRODES AS AFFECTED BY DISTANCE.

In using large carbon plates, 4 by 6 inches, for electrodes, it has been found that beyond 7 or 8 inches apart it makes very little difference in the resistance if they are placed as many feet apart. In the ordinary form, likewise, it has been found that the resistance between different sets of electrodes was hardly affected by the distance, provided they were over a foot or more apart. This indicated that the greater portion of the resistance offered by the soil between two electrodes, when separated by several feet, was encountered close to the surface of the electrodes themselves.

In order to ascertain the effect of distance on the resistance and determine the relative proportion of the resistance confined to successive distances from the electrodes, a number of small, nearly spherical carbon electrodes one-half inch in diameter were buried so that a series of distances varying by small intervals from three-fourths of an inch to 18 inches could be obtained. Two larger electrodes were buried 15 feet away and 15 feet from each other. These will be designated as A and B. The resistance between A and B was measured and the resistance between each of the small electrodes and A, and then the resistance between each of the small electrodes and B. From these measurements it was a simple matter to calculate the resistance due to each of the individual electrodes at a distance of 15 or more feet. By adding the values of any two of the small electrodes, thus found, the resistance is obtained which they would have if 15 feet apart. The actual resistance was then found between different pairs of the small electrodes. The calculated resistance of each pair when separated by 15 or more feet, and the observed resistance for the same pair when separated by the actual distance is given in the following table, together with the difference between the observed and calculated, and the percentage of the calculated represented by the observed:

Variation with distance of resistance in soil to electric current.

Distance.	Calculated resistance.	Observed resistance.	Difference.	Relation of observed to calculated resistance.
Inches.	*Ohms.*	*Ohms.*	*Ohms.*	*Per cent.*
0¾	990	610	380	62
1	980	710	270	72.5
1½	1, 050	850	200	81
2	1, 060	890	170	84
2½	1, 070	920	150	86
3	1. 140	1, 020	120	89.5
4	1, 130	1, 030	100	91
5	970	900	70	92.8
8	900	840	60	93.4
12	1, 270	1, 230	40	96.8
18	1. 430	1. 400	30	97.9

The distances were measured from center to center of the electrodes so that the nearest points of the two surfaces are one-half inch nearer than the distances given in the table. It will be noticed that when separated by 1 inch the resistance is 72.5 per cent of that when separated 15 feet and that practically 98 per cent of the resistance is encountered when the electrodes are within 18 inches of each other. This shows that when two electrodes are separated by 15 feet a layer of soil immediately surrounding each electrode of a thickness equal to one-half the distance given in the first column causes the percentage of the total resistance given in the last column. When the electrodes are

15 feet apart 98 per cent of the resistance is encountered within 9 inches of the surface of each electrode and the intervening 13½ feet of soil causes only 2 per cent of the total resistance.

CALCULATION OF RESULTS.

It has been stated that only a single standardization is necessary in most cases and with most soils. It has been found, as a result of our experience this year in all characters of soil, from the lightest sandy to the heaviest limestone clay, that the resistance of the soil varies inversely as the square of the water, calculated in per cent of the water-free soil. With only a very few exceptions, this law has held with the 64 electrodes which have been out, so that from a single standardization the moisture percentages could be calculated from the variation in the resistance throughout the season. The exceptions which are referred to are apparently due to changes in the electrodes, as in the separation of the electroplating from the carbon strips. This has not been thoroughly investigated as yet. It is possible, where this ratio of the resistance and the square of the water content does not hold exactly, to work out the actual ratio from a series of standardizations.

The general equation for deducing the moisture from the electrical resistance is given in the following simple formula:

$$W_1=\sqrt{\frac{W^2R}{R_1}}$$

where W^2 represents the square of the percentage of water found at the time of standardization, R the resistance corresponding to this water content, R_1 the resistance at any other time, and W_1 the per cent of water corresponding to the resistance R_1. The term W^2R can be used as a constant throughout the season. This is to be divided by the resistance at any other time, and the square root of the quotient will give the percentage of water at that time. This calculation can be readily and quickly made by the use of logarithms. An example will illustrate the use of the formula. At the time of standardization suppose the water content to be 16.4 per cent and the resistance corresponding to this to be 1,790 ohms, the constant is found as follows:

Log. water (16.4 per cent)	=1. 2148
	2
	2. 4296
Log. resistance (1,790)	=3. 2529
Log. constant	=5. 6825

This gives the logarithm of a constant which is used in this form for the calculation of the water content of the soil at any other time. The further calculations are made in the following way: Suppose the resistance of this set of electrodes on a subsequent date is 2,350 ohms. Find the logarithm of this number, subtract it from the logarithm of the constant, divide the remainder by 2, and find the number corresponding to this logarithm, which will be the true moisture content of the soil, thus:

Log. constant = 5.6825
Log. 2,350 = 3 3711
2)2.3114
Log. moisture = 1.1557 = 14.3 per cent.

It is well to standardize the electrodes occasionally during the season to see if they are in good order and if the constant found above continues to hold. It is well also to have the ordinary standardization when the soil is about in its average condition of moisture—that is, when it is neither too wet nor too dry for crops. On the other hand, any additional standardization during either or both of the extremes of moisture should be made when the moisture content is as different as possible from the average.

In case very accurate work is intended and thoroughly reliable moisture determination can be made, or in any soil in which the change in the resistance is not quite the same as the square of the moisture, the exact exponent may be determined in the following way: At least three standardizations should be made, and if possible four or five, during the season. The ratio of the change in the resistance to the change in the water content can then be determined from the following formula:

$$\text{Exponent} = \frac{\text{log. } R - \text{log. } R_1}{\text{log. } W_1 - \text{log. } W}$$

where R and R_1 equal the resistance at any two determinations, and W_1 and W the per cents of water corresponding to these resistances taken as whole numbers. The exponents found from different standardizations may be used for a portion of the season, or if the variation seems to indicate a chance variation in the water content they may all be averaged and the true exponent approximated, to be used throughout the season. When the ratio of the change of resistance to the changing water, or the true exponent, has thus been determined, the calculation is made in the same way as that already given. If, for example, the exponent is 1.5 instead of 2, the above calculation would be as follows:

Log. water (16.4 per cent) = 1.2148
1.5
1.8222
Log. resistance (1,790) = 3.2529
Log. constant = 5.0751

If the resistance changes to 2,350 ohms—

Log. constant = 5.0751
Log. 2,350 = 3.3711
1.5)1.7040
Log. moisture = 1.1360 = 13.7 per cent.

The method of collecting samples of soil from the field for moisture determinations is not sufficiently accurate to warrant the refinement involved in the last paragraph, and the exponent 2, or the square of the water, is sufficiently accurate for the majority of soils which have come to our attention.

THE RESULTS OF THE OBSERVATIONS DURING THE SEASON OF 1897.

It has been stated that 14 sets of these instruments were placed in the hands of farmers in widely different sections of the country and in different types of soil. The places of observations were as follows:

Fort Meade, Fla., on the fine cigar-tobacco soil (hammock land). This is a deep, sandy soil with sufficient organic matter to give it a dark color to the depth of 3 or more feet, and with proper selection and management produces a very fine cigar tobacco, quite similar to that produced in Cuba. It maintains on an average 8 per cent of moisture and carries about 1.5 per cent of clay.

Winterhaven, Fla., on a very light, sandy truck soil with about 1.3 per cent of clay, which carries at the maximum not over 5 per cent of moisture and rarely goes below 3 per cent within 3 inches of the surface even during the most prolonged drought.

Quincy, Fla., on a rolling, sandy loam tobacco soil, underlaid at a depth of 18 to 24 inches with a medium yellow clay.

James Island, on a light truck and sea-island cotton soil maintaining on an average about 9 per cent of moisture and carrying about 3.2 per cent of clay.

Newbern, N. C., on the best type of very early truck soil, sandy to a depth of 3 or more feet. This soil has about 2.8 per cent of clay and averages about 8.5 per cent of water for the crop season.

Oxford, N. C., on rolling, sandy, bright tobacco soil, underlaid at a depth of 15 to 24 inches with a yellow subsoil carrying about 8.3 per cent of clay. The soil has about 3.3 per cent of clay and maintains about 8 per cent of water.

Wilson, N. C., on bright-tobacco soil similar to that at Oxford, but slightly finer in texture and somewhat farther from clay subsoil.

West Norfolk, Va., on sandy early-truck land. The texture and water capacity of this soil is about the same as that at Newbern.

Windsor, Conn., on light, sandy tobacco soil having about 1.3 per cent of clay. This soil also makes good truck land. It maintains about 10 per cent of water.

Lititz, Pa., on the heavy limestone tobacco, corn, wheat, and grass land, maintaining on an average about 23 per cent of moisture and having in the subsoil about 36 per cent of clay.

Lexington, Ky., on the blue-grass and burley-tobacco soils, which maintain on an average about 22 per cent of moisture and have in the subsoil about 35 per cent of clay.

Germantown, Ohio, on the cigar-tobacco soil. This land is also good for corn, wheat, and grass; has in the subsoil about 27.5 per cent of clay and carries about 22 per cent of moisture.

Hopkinsville, Ky., on export-tobacco soil, which in this case is very similar to that at Germantown.

Takoma Park, Md. Here two sets of electrodes were placed on the same plat and daily samples taken for moisture determination by drying at 110° C., so as to compare the two methods.

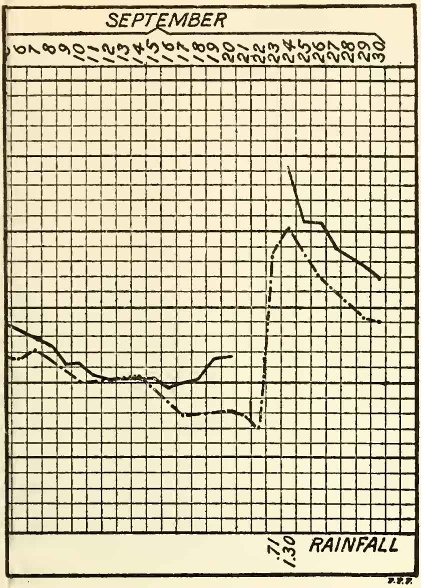
The results of the daily moisture determinations at Fort Meade and Winterhaven will be published in Bulletin No. 13 of this Division, "A preliminary report upon the soils of Florida." Those of Oxford and Wilson, N. C.; Windsor, Conn.; Lititz, Pa.; Germantown, Ohio; Lexington and Hopkinsville, Ky., in Bulletin No. 11 of this Division, "Tobacco soils of the United States." The records at Quincy, Fla., and at Portsmouth, Va., were incomplete, due to accidents with the instruments or unavoidable absence of the observers, and are not published. The accompanying tables give the daily records at Takoma Park, D. C.; James Island, S. C.; and Newbern. N. C. The diagrams show the same results in a graphic way.

Plate I, diagrams 1 and 2, show the daily variation in moisture for the 1 to 3 and 3 to 6 inch depths at Takoma Park during the months of June to September, inclusive. The unbroken line represents the moisture as determined from the electrical resistance of the soil; the broken line represents the water content, determined by drying daily composite samples at 110° C. Each composite sample was made up of four samples taken on different sides of and at the exact depth of each electrode. In each depth the same factor for RW^2 has been used throughout the entire period. It should be noticed that the lines are approximately as close together at the close of four months as they were at the beginning, showing that there has been no permanent change of any kind in the electrodes. The lines agree in the main very well. There are occasional differences that amount to 4 per cent; but this is no doubt due in part to actual difference in the moisture content in the soil immediately around the electrodes and where the samples were taken, as an equal variation may occur in duplicate samples, as seen by comparing the results of 16 composite samples given on page 12.

Plate II, diagram 3, gives the daily record, as determined from the electrical resistance, for the 3 to 6 and 9 to 12 inch depths at James Island, South Carolina, the 21 to 24 inch depth being omitted because the line so nearly corresponded with those given as to make the diagram confusing. Composite samples were taken for each depth at intervals of a week or ten days during the greater portion of the season, the results of which are shown by the crosses. The solid cross corresponds to the unbroken line and the four dots to the broken line. The agreement of the two methods for the season is remarkably close.

Plate II, diagram 4, gives the results at Newbern, N. C. The land used was planted to pease and the electrodes placed in a row. The first break in the record, caused by absence of the observer, was unfortunate, as it happened during a very dry period, there having been no rain from May 14 to June 5. In the case of the second break the record was lost in the mail. There were only five sets of samples taken during

PLATE I.


SEPTEMBER
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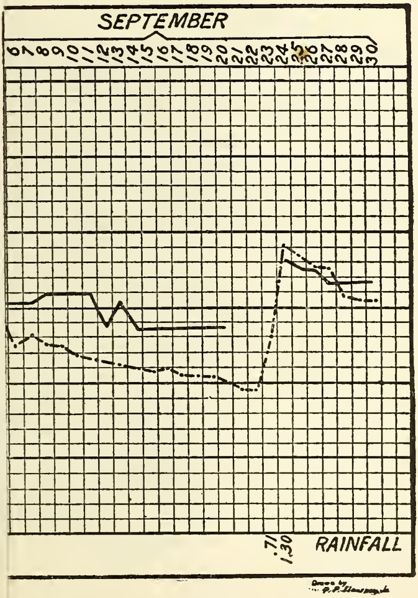
RAINFALL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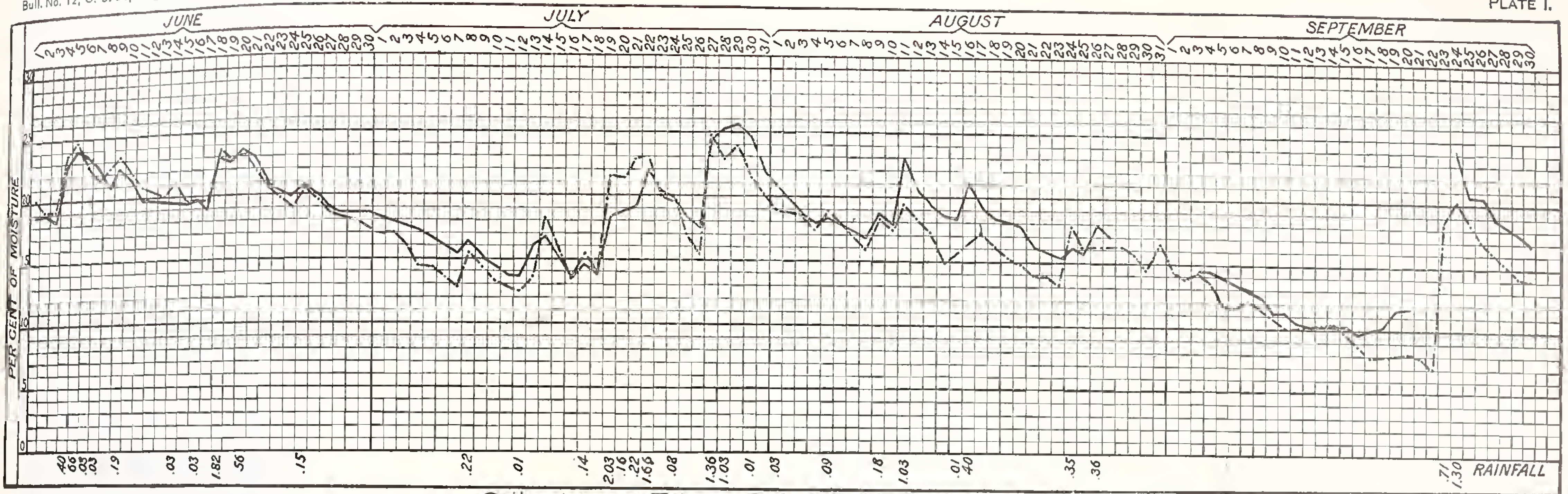
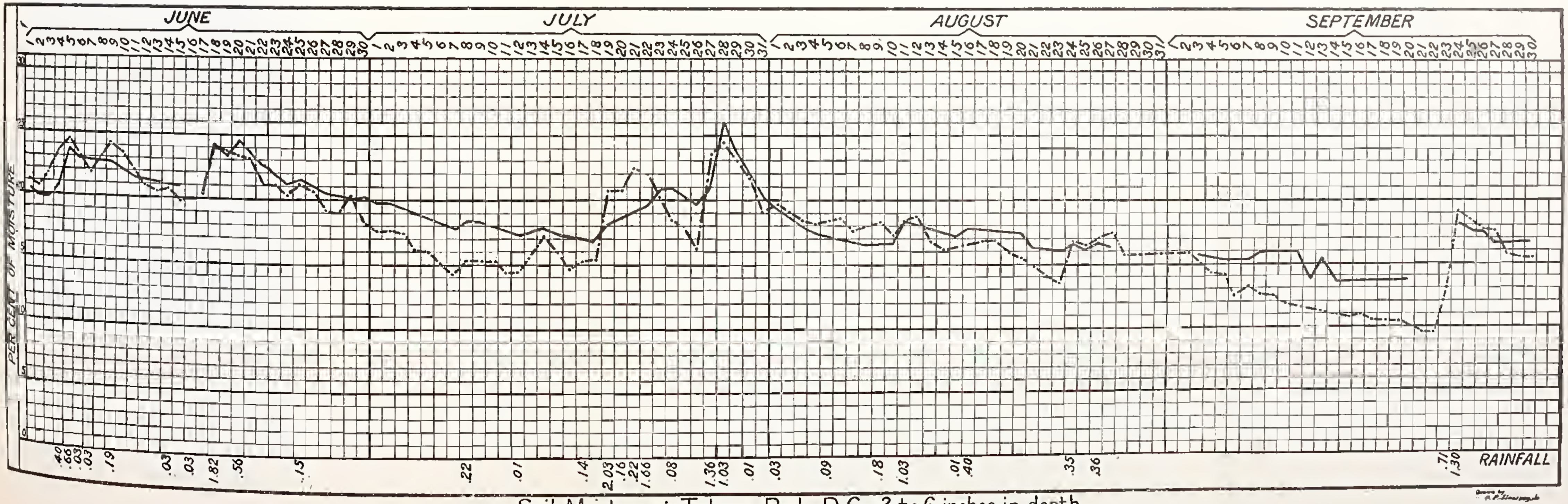


Soil moisture at Takoma Park, D.C., 1 to 3 inches in depth.
By the electrical method ———— By drying samples at 110° C. —.—.—.

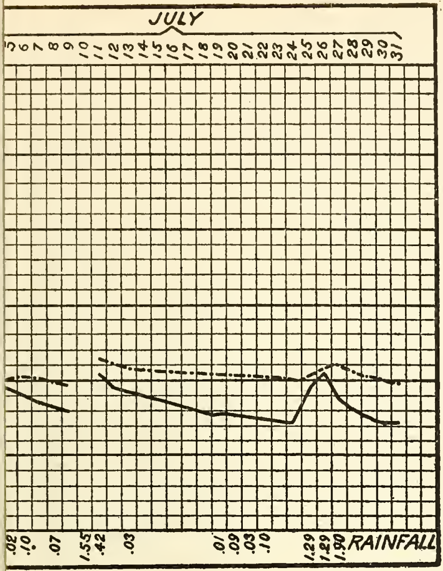
DIAGRAM 1.

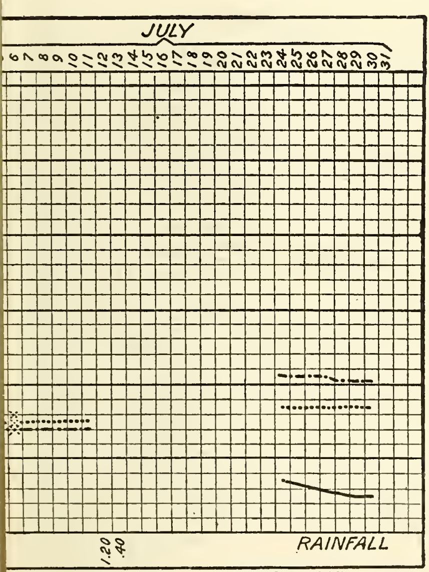


Soil Moisture at Takoma Park, D.C., 3 to 6 inches in depth
By the electrical method ———— By drying samples at 110°C. —.—.—.

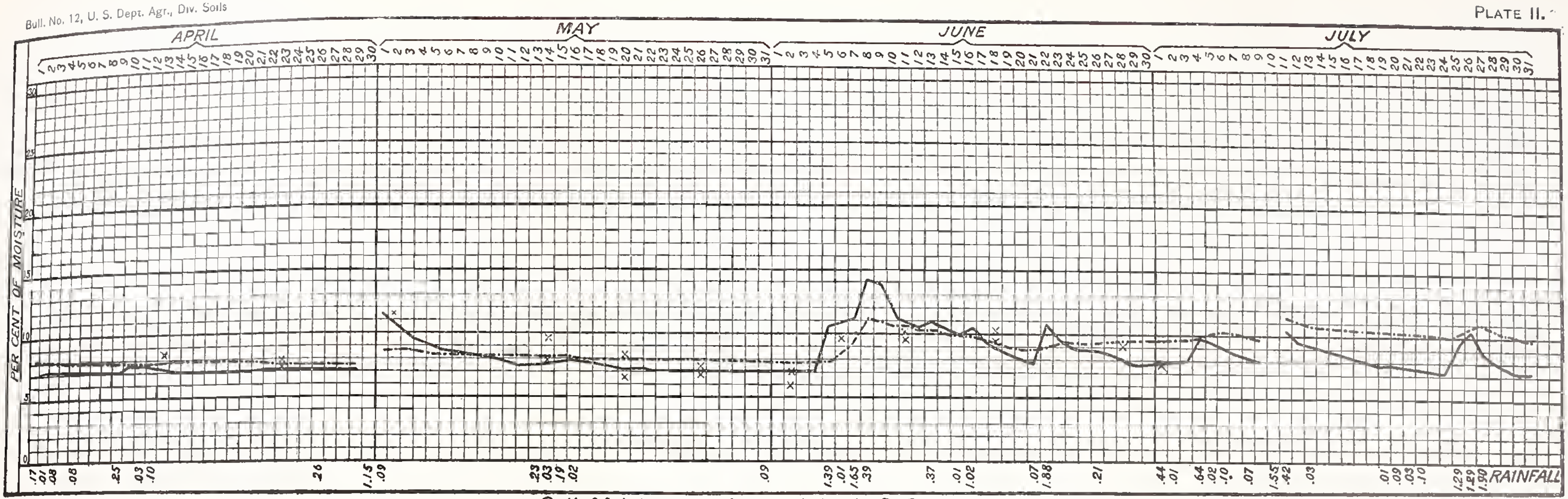
DIAGRAM 2.

PLATE II.



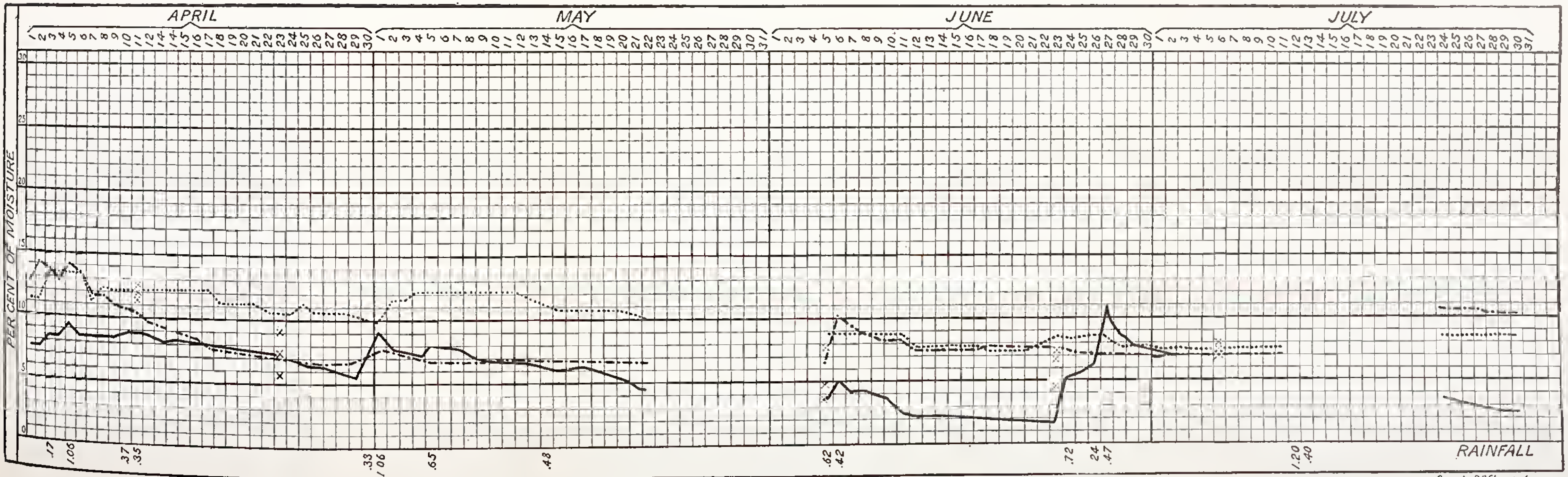


Drawn by P. P. Flournoy, Jr.



Soil Moisture at James Island, S. C.,
3 to 6 inches in depth ——— x 9 to 12 inches, —·—·— x

DIAGRAM 3.

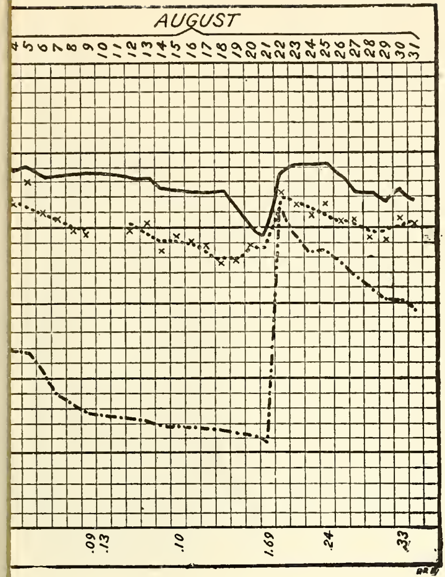


Drawn by P. P. Flournoy, Jr.

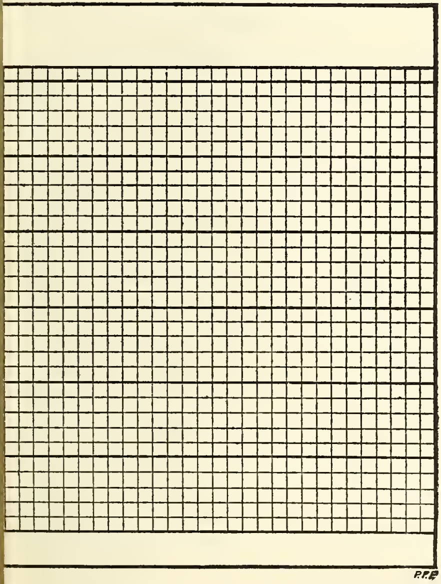
Soil Moisture at Newbern, N. C.
3 to 6 inches in depth ——x, 9 to 12 inches —·—·x, 21 to 24 inches ·········x

DIAGRAM 4.

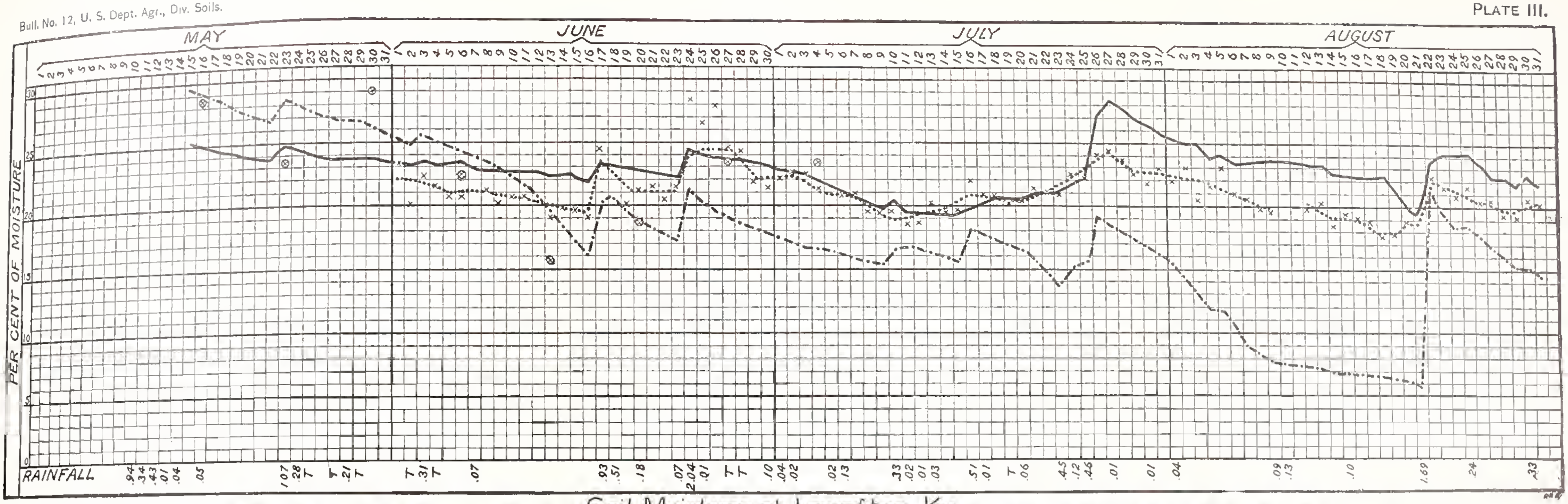
PLATE III.



ubes, 0 to 12 in. ··········×



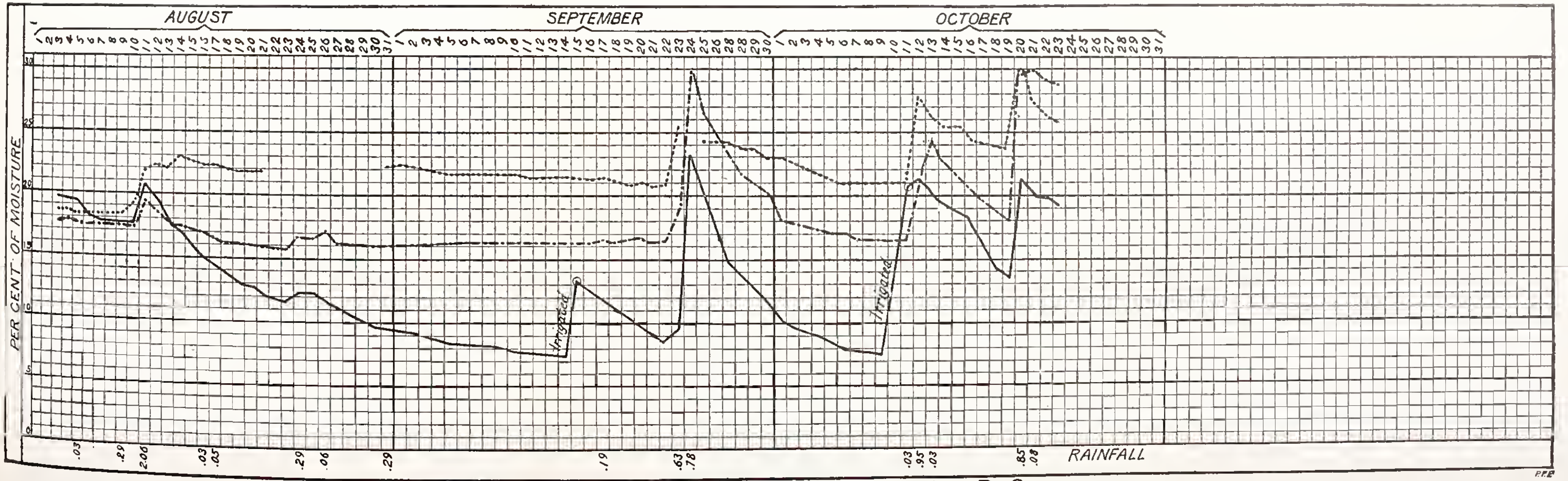
n.



Soil Moisture at Lexington, Ky.

Blue grass sod, 3 to 6 in. —·—·— Bare land, uncultivated, 3 to 6 in. ——— ⊗ Daily samples of the latter in brass tubes, 0 to 12 in. ·········×

DIAGRAM 5.



Soil Moisture at Department Grounds, Washington, D.C.

Bare, uncultivated —·—·— Mulched with lawn cuttings ·········. Growing wheat ——— All for depths, 3 to 6 in.

DIAGRAM 6.

the season and they agree fairly well with the determinations by the electrical method.

Although the moisture record for 3 to 6 inches in the grass sod at Lexington, Ky., was given in the Bulletin on Tobacco Soils, it is given again here in a graphic way on Plate III, diagram 5, in comparison with the record for the same depth on an adjacent plat which was free of vegetation and had the surface cultivated occasionally. The unbroken line represents the daily record of moisture in the bare cultivated plat, while the broken line gives a similar record for the grass sod. It shows very plainly the effect of the grass in reducing the supply of soil moisture. On the diagram is also shown the daily record of soil moisture in the bare land for 0 to 12 inches during the months of June, July, and August, as determined by the old method of taking a daily sample in a brass tube, covering the ends with rubber caps and sending by mail to the Department laboratory, where the moisture in the sample was determined by drying for about twenty hours at 110° C. The crosses represent the actual daily determinations, while the dotted line is an approximate mean of them and eliminates to a certain extent the differences due to the variation in the soil. The records of the two methods here given are not comparable because they represent different depths, but as a matter of fact the lines follow each other fairly well and indicate that the moisture at 3 to 6 inches in depth represents about the same as that for the first 12 inches in depth. The crosses within the circles represent the per cent of moisture at 3 to 6 inches in the bare soil as determined by drying composite samples.

Plate III, diagram 6, gives the results for 3 to 6 inches in plats 1, 5, and 6 on the United States Department grounds for August, September, and the greater part of October. Previous to starting the experiments, August 3, the plats had been treated alike, and it will be noticed that they were very uniform as to water content during the first week. Plat 1 was seeded to wheat on August 7, and in four days the plants were practically all up and from that time grew remarkably fast, as can be seen from the great draft they made on the moisture of the plat, graphically shown in the chart. At the time of sowing the wheat plat 6 was mulched with lawn cuttings. Plat 5 was allowed to remain bare and undisturbed during the entire time. The heavy rain of 2.06 inches on August 11 shows but slight effect on the plats, due to the fact that it fell in torrents and most of it ran off the surface.

The bare plat maintained its moisture at 16 per cent even during the long, dry periods, while the mulched plat held 21 per cent or more during the whole time. Plat 1 became very dry, and wherever the moisture line falls below 9 per cent the wheat ceased to make any growth and some of the leaves died.

MOISTURE RECORDS AS DEDUCED FROM THE ELECTRICAL RESISTANCE OF SOILS.

The accompanying tables give the remainder of the unpublished records of this season from which the charts are drawn. It will be remembered in studying these data that the length of time between the fall of rain and the determination of the amount of water in the soil will have a great influence upon the apparent effect of the rainfall in increasing the soil moisture. The moisture content of the soil near the surface decreases very rapidly immediately after a rain, and as the determinations are made only once in twenty-four hours it may happen that the measurement is taken twenty hours or more after the rain has ceased to fall. It is quite common, therefore, to find that small rainfalls do not show any influence on the moisture records, and even very large rainfalls have much less effect at one time than at another, depending upon the way the rain falls and the condition of the soil.

NOTE ON A MODIFICATION OF THE ELECTRICAL METHOD OF DETERMINING THE SOLUBLE SALT CONTENT OF SOILS—BY THOS. H. MEANS.

In the method of determining the soluble salt content of soils, described in Bulletin No. 8 of this Division, the soil is mixed with a definite quantity of water, packed in a cell with parallel electrodes, and the electrical resistance determined. The same quantity of soil is then mixed with a like quantity of salt solution having a known salt content and the resistance again determined. It has been found that this method is not applicable to soils containing a large amount of soluble salt, as with the alkali soils of the West, for the salt added materially changes the amount of dissociated salt in the soil. This led to a careful review of the work which had previously been done, and it appears probable that the apparent influence of the texture of the soil, mentioned on page 26 of Bulletin No. 8, is largely due to the effect of the added salt upon the dissociated salt content of the soil. Correcting for this, the influence of the texture of a soil upon the resistance of a solution seems to be a constant which does not vary with the nature of the soil, provided the soil is thoroughly saturated with water. This factor has not been established with great accuracy as yet, but it appears to be approximately .54 or .56. This is the ratio between the resistance of a strong salt solution in a cell with parallel electrodes and that of the same amount of salt solution saturated with a soil in the same cell.

In making a determination the soil is thoroughly saturated with water and worked with a spatula so that the water is evenly distributed through it. The cell is then filled with this moist material, which is so wet that it can not be packed closely, but not so wet that water will be squeezed from it in filling the cell. The resistance is multiplied by the factor for texture. This will give the resistance of an amount of water equal to that in the cell without the presence of the soil added. The specific resistance of the solution can thus be determined, and on comparing this with the specific resistance of sodium chloride solutions of different strengths the amount of salt can readily be determined. This calculation can be made in terms of the moist soil or in terms of dry soil. It is applicable to all soils, whether they contain much or little of soluble salts, and gives the relative quantity of soluble salt present, with a very small probable error.

Moisture record as deduced from the electrical resistance of soils at Takoma, D. C.

Day of month. (1897.)	May.				June.					July.				
	1 to 3 inches.	3 to 6 inches.	9 to 12 inches.	Rain.	1 to 3 inches.	3 to 6 inches.	9 to 12 inches.	21 to 24 inches.	Rain.	1 to 3 inches.	3 to 6 inches.	9 to 12 inches.	21 to 24 inches.	Rain.
	Per ct.	*Per ct.*	*Per ct.*	*Ins.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Ins.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Ins.*
1...	8.83	16.92	18.86	0.40	18.77	20.35	20.34	18.72	.....	18.16	19.90	20.22	17.81	.....
2...	20.04	18.01	18.72	.06	18.90	19.97	20.53	18.72	.....	17.93	19.75	20.22	17.73	.....
3...	18.16	20.67	19.05	.49	18.40	19.90	20.65	18.46	.....	17.50	19.27	19.87	17.66	.....
4...	21.43	22.33	20.04	.....	22.68	20.76	20.99	18.72	0.40	17.10	18.95	19.64	17.59	.....
5...	20.62	21.93	19.81	.25	23.91	23.81	20.99	18.72	.66	16.63	18.52	19.64	17.51	.....
6...	19.03	21.45	19.53	.....	23.40	22.98	20.99	18.72	.03	15.81	18.18	19.42	17.51	.....
7...	14.52	20.12	19.47	.....	22.68	22.65	20.65	18.72	.03	15.09	17.91	19.42	17.44	.....
8...	12.48	19.41	19.05	.....	20.70	22.65	20.36	18.63	.....	16.47	18.52	19.27	17.30	0.22
9...	10.93	18.64	18.72	.....	22.24	22.54	20.53	18.72	.19	15.05	18.39	19.16	17.30	.....
10...	9.49	18.27	18.48	.....	21.43	22.13	20.53	18.63	.....	14.23	18.07	19.05	17.16	.....
11...	8.70	18.07	18.25	.02	19.89	21.45	20.36	18.46	.....	13.80	17.80	19.00	17.16	.....
12...	17.93	21.69	18.48	.51	19.59	21.18	20.16	18.46	.....	13.55	17.35	18.86	16.95	.01
13...	34.99	28.78	21.19	2.81	19.59	21.18	20.04	18.38	.....	16.03	17.68	18.95	17.02	.....
14...	24.75	28.57	24.42	.31	19.31	21.01	19.93	18.29	.03	16.90	17.91	18.95	16.95	.....
15...	23.91	25.78	26.33	.04	19.17	21.01	19.93	18.21	.....	15.09	17.60	18.95	16.95	.....
16...	23.15	24.13	22.92	.....	19.45	....	....	....	.03	13.80	17.25	19.01	16.95	.....
17...	21.62	22.88	22.49	.....	18.67	20.51	19.70	18.38	.....	14.64	17.06	18.86	16.89	.14
18...	19.90	21.64	21.93	.....	22.91	24.19	20.60	18.72	1.82	13.80	16.97	18.86	16.89	.....
19...	18.90	20.92	21.78	.....	22.69	23.20	20.34	18.72	.....	18.40	18.12	18.95	16.89	2.03
20...	18.67	20.51	21.48	.....	23.64	24.88	21.06	18.72	.56	18.77	18.64	19.32	16.89	.16
21...	18.28	20.12	21.19	.06	23.15	23.81	20.99	18.72	.....	19.19	19.34	19.32	17.16	.22
22...	17.93	19.62	21.06	.....	20.87	22.65	20.85	18.72	.....	22.05	19.68	....	18.72	1.66
23...	17.93	18.95	20.92	.....	20.20	21.93	20.60	18.55	.....	20.20	21.10	....	18.55	.....
24...	22.46	22.03	21.78	.86	19.74	21.27	20.16	18.29	.....	19.74	21.01	21.19	18.38	.08
25...	22.46	22.44	26.00	.69	20.70	21.64	20.04	18.29	.15	18.16	20.19	20.65	18.29	.....
26...	20.20	21.18	21.41	.....	20.04	21.18	20.10	18.29	.....	17.30	19.68	....	18.29	.....
27...	19.17	20.59	21.13	.....	18.90	20.59	19.93	18.26	.....	24.17	21.01	....	19.54	1.36
28...	18.52	20.19	20.65	.....	18.52	20.36	19.59	18.21	.....	25.36	26.11	....	19.54	1.03
29...	18.16	19.68	20.53	.....	18.40	20.12	20.41	18.05	.....	25.68	23.81	....	19.54	.....
30...	17.93	20.04	20.53	.....	18.52	20.19	20.28	17.88	.....	24.75	22.03	....	19.18	.01
31...	18.19	19.98	20.65	.....	....	....	....	....	.....	22.03	20.19	....	18.72	.....

Day of month. (1897.)	August.				September.			
	1 to 3 inches.	3 to 6 inches.	21 to 24 inches.	Rain.	1 to 3 inches.	3 to 6 inches.	21 to 24 inches.	Rain.
	Per ct.	*Per ct.*	*Per ct.*	*Inches.*	*Per ct.*	*Per ct.*	*Per ct.*	*Inches.*
1..................................	21.06	19.68	18.72	0.03	....	....	....	....
2..................................	19.45	18.82	18.72	....	....	....	....	....
3..................................	18.52	18.18	18.72	....	14.57	15.71	18.21	....
4..................................	17.93	17.54	18.63	....	14.34	15.64	18.05	....
5..................................	18.28	17.16	18.63	.09	13.80	15.47	17.88	....
6..................................	17.93	17.11	18.63	....	13.27	15.47	18.72	....
7..................................	17.30	16.97	18.55	....	12.88	15.40	18.29	....
8..................................	16.81	16.70	18.46	....	12.48	16.02	18.29	....
9..................................	18.77	16.84	18.29	.18	11.20	16.02	18.12	....
10..................................	17.82	16.84	18.29	....	11.18	16.02	18.12	....
11..................................	23.15	18.52	18.29	1.03	10.61	16.02	18.12	....
12..................................	20.70	18.07	18.55	....	10.14	13.62	17.37	....
13..................................	19.39	17.80	18.55	....	10.14	15.37	17.44	....
14..................................	18.52	17.40	18.55	....	10.10	13.62	17.37	....
15..................................	18.04	17.30	17.66	.01½	10.14	13.62	17.37	....
16..................................	21.06	17.85	18.46	.40	9.94	13.58	17.16	....
17..................................	19.17	17.70	18.46	....	9.94	13.58	17.16	....
18..................................	18.52	17.64	18.46	....	10.14	13.58	17.23	....
19..................................	18.09	17.54	18.29	....	11.48	13.62	17.16	....
20..................................	17.40	17.54	18.29	....	11.63	13.62	16.83	....
21..................................	16.03	16.41	18.55	....	....	....	....	....
22..................................	15.50	16.21	18.55	....	....	....	....	....
23..................................	15.16	16.13	18.29	....	....	....	....	0.71
24..................................	16.03	16.62	18.29	.35	24.45	18.24	18.72	1.30
25..................................	15.65	16.21	18.29	....	20.53	17.60	16.51	....
26..................................	17.93	16.84	18.72	.36	20.53	17.60	16.51	....
27..................................	16.90	16.41	18.29	....	18.90	16.84	16.83	....
28..................................	....	....	....	....	18.28	16.79	16.83	....
29..................................	....	....	....	....	17.88	16.79	16.69	....
30..................................	....	....	....	....	16.90	16.62	16.69	....
31..................................	....	....	....	....	....	....	....	....

Moisture record as deduced from electrical resistance of soils at James Island, S. C.

Day of month. (1897.)	April.				May.			
	3 to 6 inches.	9 to 12 inches.	21 to 24 inches.	Rain.	3 to 6 inches.	9 to 12 inches.	21 to 24 inches.	Rain.
	Per ct.	*Per ct.*	*Per ct.*	*Inch.*	*Per ct.*	*Per ct.*	*Per ct.*	*Inch.*
1	7.01	8.20	12.76	0.17	11.42	8.55	7.89	0.09
2	7.21	8.07	12.28	.01	10.54	8.75	7.92	....
3	7.18	7.96	11.86	.08	9.58	8.58	7.92	....
4	7.09	7.90	11.53	....	9.13	8.55	8.05	....
5	7.08	7.91	11.05	.08	8.76	8.37	8.00	....
6	....	....	....	....	8.49	8.37	8.01	....
7	6.98	7.76	10.08	....	8.32	8.37	7.94	....
8	6.97	7.73	10.10	....	8.05	8.26	7.83	....
9	6.98	7.73	9.79	.25	8.03	8.22	7.92	....
10	7.63	7.67	9.66	....	7.80	8.20	7.80	....
11	7.62	7.73	9.51	.03	7.49	8.16	7.72	....
12	7.43	7.76	9.35	.10	7.41	8.18	7.78	....
13	7.14	7.97	9.21	....	7.39	8.09	7.67	.23
14	6.98	7.90	9.08	....	7.54	8.03	7.71	.03
15	6.98	7.91	8.97	....	7.75	8.27	7.76	.19
16	6.98	7.90	8.87	....	7.87	7.98	7.69	.02
17	6.97	7.85	8.77	....	7.64	7.95	....	....
18	6.97	7.78	8.66	....	7.44	7.87	....	....
19	6.97	7.73	8.49	....	7.27	7.98	8.50	....
20	6.97	7.67	8.41	....	7.14	7.97	8.22	....
21	7.12	7.66	8.37	....	7.14	7.98	8.08	....
22	7.13	7.52	8.28	....	7.01	7.95	8.02	....
23	7.13	7.49	8.20	....	6.97	7.98	7.94	....
24	7.12	7.49	8.12	....	6.98	7.95	7.91	....
25	7.13	7.48	8.04	....	6.98	7.86	7.86	....
26	7.12	7.49	7.98	.06	6.97	7.84	7.86	....
27	7.11	7.49	7.98	....	6.97	7.82	7.87	....
28	7.12	7.48	7.92	....	6.97	7.79	8.56	....
29	7.12	7.49	7.94	....	6.96	7.82	8.48	....
30	....	....	....	1.15	6.96	7.73	8.40	....
31	....	....	....	....	6.96	7.75	8.26	.09

Day of month. (1897).	June.				July.			
	3 to 6 inches.	9 to 12 inches.	21 to 24 inches.	Rain.	3 to 6 inches.	9 to 12 inches.	21 to 24 inches.	Rain.
	Per ct.	*Per ct.*	*Per ct.*	*Inch.*	*Per ct.*	*Per ct.*	*Per ct.*	*Inch.*
1	6.96	7.66	8.26	....	7.45	9.44	9.04	0.44
2	6.96	7.71	8.19	....	7.90	9.44	9.23	.01
3	6.96	7.65	8.10	....	7.73	9.44	9.08	....
4	6.96	7.63	8.07	....	9.71	9.87	9.27	.64
5	10.54	7.68	8.00	1.39	....	....	....	.02
6	10.77	8.49	8.36	.01	8.70	10.11	9.39	.10
7	11.02	9.43	8.37	1.65	8.40	10.07	....	....
8	14.13	11.06	9.82	.39	8.13	9.96	9.33	.07
9	13.57	10.91	9.64	....	7.78	9.92	9.27	....
10	11.33	10.52	9.39	....	....	....	....	1.55
11	10.75	10.40	9.11	....	11.29	11.29	10.71	.42
12	10.24	10.11	9.01	....	9.35	10.94	10.80	....
13	10.91	10.14	8.92	.37	9.08	10.76	10.53	....
14	10.27	10.03	8.90	....	8.83	10.64	10.40	....
15	9.75	9.92	8.75	.01	8.55	10.53	10.18	....
16	10.34	9.83	9.17	1.02	8.22	10.45	9.98	....
17	9.40	9.31	9.25	....	....	....	....	....
18	8.78	9.10	9.17	....	7.79	10.21	9.79	....
19	8.38	8.96	9.06	....	7.55	10.19	9.75	.01
20	7.93	8.84	8.82	....	7.52	10.14	9.59	.09
21	7.55	8.81	8.90	.07	7.34	10.09	9.66	.03
22	10.51	9.05	8.80	1.88	7.26	10.09	9.55	.10
23	9.44	9.48	9.51	....	7.01	9.92	9.47	....
24	8.76	9.25	9.53	....	7.01	9.85	9.53	....
25	....	....	....	....	9.32	10.11	9.47	1.29
26	8.53	9.28	9.33	.21	10.48	10.73	9.77	1.29
27	8.28	9.33	9.25	....	8.62	10.85	11.62	1.90
28	7.96	9.35	9.19	....	7.87	10.29	11.19	....
29	7.33	9.33	9.15	....	7.39	10.13	10.96	....
30	7.49	9.33	9.06	....	7.05	9.90	10.71	....
31	....	....	....	....	7.02	9.72	10.42	....

Moisture record as deduced from electrical resistance of soils at Newbern, N. C.

Day of month. (1897.)	April.				May.			
	3 to 6 inches.	9 to 12 inches.	21 to 24 inches.	Rain.	3 to 6 inches.	9 to 12 inches.	21 to 24 inches.	Rain.
	Per ct.	*Per ct.*	*Per ct.*	*Inch.*	*Per ct.*	*Per ct.*	*Per ct.*	*Inch.*
1	7.46	12.60	11.31	....	9.18	7.91	9.90	1.60
2	7.46	14.21	11.31	....	7.61	7.57	11.48	....
3	8.33	13.60	13.30	0.17	7.46	7.45	11.64	....
4	8.33	12.60	13.30	....	7.11	7.10	12.18	....
5	9.62	14.21	13.30	1.06	8.14	6.87	12.18	.65
6	8.33	13 60	13.30	....	7.86	6.80	12.18	....
7	8.33	11.79	11.31	....	7.77	6.80	12.18	....
8	8.33	11.79	12.37	....	7.46	6.70	12.18	....
9	8.33	11.11	12.18	....	6.81	6.70	12.18	....
10	8.79	10.81	12.18	.37	6.81	6.70	12.18	....
11	8.91	10.41	12.18	.35	6.81	6.70	12.18	....
12	8.44	9.94	....	....	6.81	6.70	12.18	....
13	8.14	9.43	12.37	....	6.64	6.68	11.64	....
14	8.14	9.16	12.37	....	6.30	6.68	11.31	.48
15	8.14	8.83	12.37	....	6.13	6.68	10.85	....
16	7.86	8.65	12.18	....	6.13	6.68	10.85	....
17	7.86	8.02	12.18	....	6.13	6.68	10.85	....
18	7.77	7.75	11.31	....	6.05	6.68	10.85	....
19	7.61	7.75	11.31	....	5.72	6.68	10.85	....
20	7.53	7.44	11.31	....	5.33	6.68	10.70	....
21	7.53	7.27	11.31	....	4.53	6.68	10.42	....
22	7.46	7.23	10.70	....	4.39	6.68	10.28	....
23	7.12	7.19	10.56	....	....	....	....	....
24	6.81	6.95	10.56	....	....	....	....	....
25	6.54	6.77	11.31	....	....	....	....	....
26	6.30	6.70	10.60	....	....	....	....	....
27	6.13	6.73	10.70	....	....	....	....	....
28	5.89	6.73	10.56	....	....	....	....	....
29	5.68	6.73	10.42	....	....	....	....	....
30	7.05	7.03	10.15	.33	....	....	....	....
31	....	....	....	....	....	....	....	....

Day of month. (1897.)	June.				July.			
	3 to 6 inches.	9 to 12 inches.	21 to 24 inches.	Rain.	3 to 6 inches.	9 to 12 inches.	21 to 24 inches.	Rain.
	Per ct.	*Per ct.*	*Per ct.*	*Inch.*	*Per ct.*	*Per ct.*	*Per ct.*	*Inch.*
1	....	....	....	....	7.11	6.97	7.66	....
2	....	....	....	....	7.11	7.10	7.66	....
3	....	....	....	....	....	7.10	7.66	....
4	....	....	....	....	....	7.12	7.66	....
5	3.51	6.80	8.90	0.62	....	7.15	7.66	....
6	5.14	10.19	8.90	.42	....	7.23	7.66	....
7	4.25	9.43	8.90	....	....	7.23	7.66	....
8	4.14	9.11	8.90	....	....	7.23	7.66	....
9	3.73	8.60	8.85	....	....	7.23	7.66	....
10	3.41	8.51	8.85	....	....	7.23	7.66	....
11	2.72	8.46	8.85	....	....	7.23	7.66	....
12	2.19	7.57	7.96	....	....	7.10	7.77	1.20
13	2.18	7.56	7.96	....	....	7.10	7.77	.40
14	2.17	7.53	7.96	....	....	7.10	7.77	....
15	2.17	7.53	7.96	....	....	7.23	7.80	....
16	2.03	7.62	7.80	....	....	7.53	7.83	....
17	1.99	7.69	7.80	....	....	....	....	....
18	1.86	7.76	7.39	....	....	....	....	....
19	1.86	7.69	7.39	....	....	....	....	....
20	1.86	7.69	7.39	....	....	....	....	....
21	1.81	7.69	7.39	....	....	....	....	....
22	1.68	7.71	8.12	....	....	....	....	....
23	1.59	7.72	8.48	....	....	....	....	....
24	5.27	7.53	8.48	.72	3.50	10.64	8.48	....
25	5.56	7.23	8.68	....	3.12	10.64	8.68	....
26	6.30	7.22	8.68	.24	2.90	10.64	8.68	....
27	10.54	7.12	8.12	.47	2.91	10.65	8.68	....
28	8.91	7.10	7.80	....	2.63	10.23	8.68	....
29	7.86	7.08	7.80	....	2.48	10.23	8.68	....
30	7.69	7.05	7.74	....	2.48	10.23	8.68	....
31	....	....	....	....	....	....	....	....

Moisture record as deduced from electrical resistance of soils at grounds of U. S. Department of Agriculture, Washington, D. C.

Day of month (1897.)	August.				September.				October.			
	Wheat.	Bare.	Mulched.	Rain.	Wheat.	Bare.	Mulched.	Rain.	Wheat.	Bare.	Mulched	Rain.
	Per ct.	*Per ct.*	*Per ct.*	*Inch.*	*Per ct.*	*Per ct.*	*Per ct.*	*Inch.*	*Per ct.*	*Per ct.*	*Per ct.*	*Inch.*
1	......	......	......	......	9.38	16.15	22.43	......	10.16	18.05	22.99	......
2	......	......	......	......	9.17	16.27	22.25	......	9.57	17.80	22.43	......
3	19.75	17.80	18.75	......	......	......	......	......	......	......	......	......
4	19.58	17.97	18.75	......	8.73	16.24	21.90	......	8.90	17.34	21.66	......
5	19.41	17.80	18.56	0.03	......	......	......	......	8.39	17.07	21.19	......
6	18.26	17.64	18.65	......	......	......	......	......	7.95	17.07	20.97	......
7	17.77	17.49	18.56	......	8.33	16.32	21.73	......	7.69	16.46	20.97	......
8	......	......	......	......	8.19	16.32	21.73	......	7.54	16.44	20.97	......
9	17.82	17.76	18.56	.29	7.95	16.44	21.73	......	7.36	16.44	20.97	......
10	17.54	17.52	19.18	......	7.84	16.38	21.73	......	......	......	......	......
11	20.50	19.74	21.90	2.06	7.73	16.32	21.57	......	[a] 20.50	16.38	20.97	0.03
12	19.49	18.57	22.43	......	......	......	......	......	21.33	20.91	27.77	.95
13	17.77	17.88	22.25	......	7.59	16.32	21.41	......	19.88	24.20	26.28	.03
14	16.98	17.64	23.00	......	7.46	16.38	21.57	......	19.09	22.47	25.42	......
15	......	......	......	......	[a] 13.22	16.38	21.41	......	18.79	21.16	25.42	......
16	14.92	17.06	22.43	.03	12.58	16.38	21.41	......	17.77	20.37	24.63	......
17	14.02	16.38	22.43	.05	11.82	16.61	21.41	0.19	......	......	......	......
18	13.54	16.29	22.07	......	11.26	16.55	21.10	......	14.13	18.51	23.93	......
19	12.97	16.21	21.90	......	......	......	......	......	13.22	18.09	23.93	......
20	12.74	16.10	21.90	......	9.57	16.73	20.95	......	21.27	29.49	30.32	.85
21	12.05	16.05	21.90	......	8.90	16.55	20.66	......	19.93	29.88	27.26	.08
22	......	......	......	......	8.47	16.57	20.81	......	19.54	29.13	26.82	......
23	11.60	15.95	......	......	9.52	18.71	25.35	.63	19.17	28.76	25.42	......
24	12.45	16.83	......	.29	23.26	29.87	......	.78	......	......	......	......
25	12.30	16.61	20.13	......	19.93	26.76	24.28	......	......	......	......	......
26	11.82	17.20	20.13	.06	......	......	......	......	......	......	......	......
27	11.21	16.32	20.13	......	14.72	22.94	24.28	......	......	......	......	......
28	10.71	16.35	......	......	12.74	21.63	23.93	......	......	......	......	......
29	......	......	......	......	11.65	20.91	23.93	......	......	......	......	......
30	9.52	16.05	......	......	10.86	20.21	22.99	......	......	......	......	......
31	9.52	16.21	22.25	.09	......	......	......	......	......	......	......	......

[a] Irrigated.